# Permitting and Field Inspection Best Practices—A SolarABCs and U.S. Dept. of Energy Perspective

Presented by

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# Presentation Overview

- What is the US DOE history related to permitting and field inspection of solar energy systems?
- What is Solar ABCs?
- What resources currently exist to help guide the process?
- Next Steps
- Questions??

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# What is the US DOE history related to permitting and field inspection of solar energy systems?

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# DOE involvement in the 1980's

- In 1980, Sandia National Labs led a task force for the development of Article 690, Solar Photovoltaic Systems, for the National Electrical Code.
- Throughout the 80's the U.S. Dept. of Energy (DOE) was heavily involved in standards development and standards implementation for solar thermal and solar electric systems.
- DOE helped several manufacturers develop their products to meet standards and comply with various utility and jurisdictional requirements.

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# DOE involvement in the 1990's

- In the mid-1990's, DOE organized a technical review committee, operated by the Solar Energy Industries Association (SEIA) to update the National Electrical Code (NEC).
- 30+ industry leaders participated and produced a revised version for the 1999 NEC revision.
- At the same time, IEEE 929 was completed and published in January 2000, which paved the way for utility interconnection on a large scale.

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# DOE involvement in this decade

- DOE funds John Wiles of New Mexico State University to present training to various jurisdictions throughout the U.S. and to write articles for various periodicals on NEC issues.
- In 2004, they commissioned Pace University to develop an inspector guidelines to help organize the plan check and inspection processes.
- In 2007, they established the Solar America Board for Codes and Standards (SolarABCs) to organize efforts in codes and standards throughout

the U.S.

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# What is Solar ABCs?

- It is a board of industry leaders in the codes and standards arena—many of which have been working in the field for 2 or more decades.
- It improves responsiveness, effectiveness, and accessibility of codes and standards to U.S. solar stakeholders at all levels.
- The Solar ABCs enhances the practice of developing, implementing, and disseminating solar codes and standards

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# What resources currently exist to help guide the process?

- John Wiles' (NMSU) suggested practices and checklist.
- Pace University's Inspector Guidelines.
- SolarTech's Standard Permit Application.
- ICC Tri-Chapter Uniform Code Committee (TUCC).

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# John Wiles' (NMSU) suggested practices and checklist

- Versions date back to the 1990's
- Mr. Wiles has assisted the industry in understanding code requirements through his writings and resources.

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# CHECKLIST FOR PHOTOVOLTAIC POWER SYSTEM INSTALLATIONS

- **Covers:**
  - **PV Arrays**
  - **Overcurrent Protection**
  - **Electrical Connections**
  - **Charge Controllers**
  - **Disconnects**
  - **Inverters**
  - **Batteries**
  - **Grounding**

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# Pace University's Inspector Guidelines

- Written by Bill Brooks in 2004 to develop a standardized method for permit submittals and Field Inspections.
- Widely used by jurisdictions throughout California, the U.S., and beyond.

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# Contents of Guidelines

- Introduction/Rational for Guidelines
- Permit Guidelines for Small-Scale PV Systems
  - Site Diagram
  - One-line Diagram
  - Major Component and Array Electrical Information
  - Provisions for PV Power Source Disconnect
  - Array Mounting Information
  - Costs of Permits
- Field Inspection Guideline
  - Equipment, conduit, and wiring installed according to plans
  - Structure attached according to plans and directions
  - Appropriate signs installed

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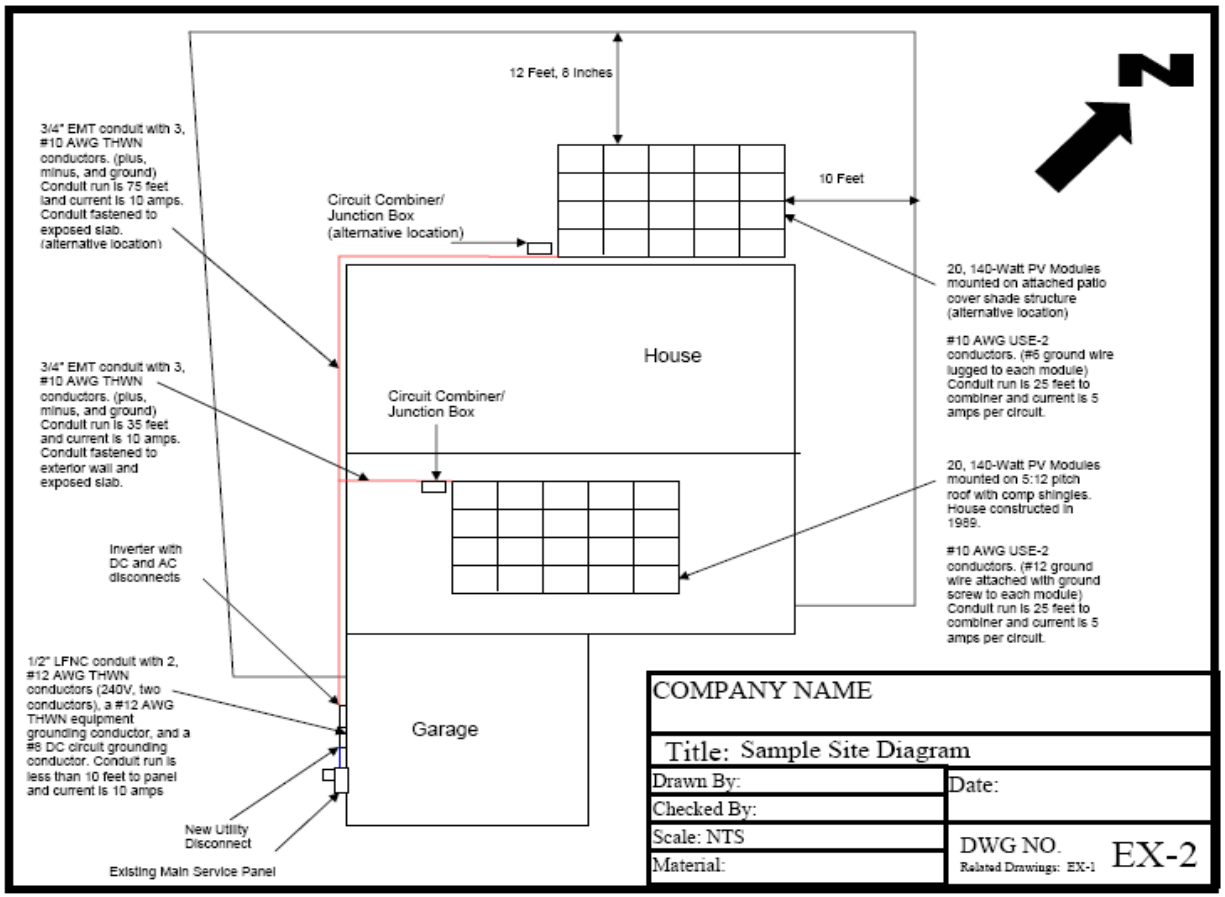
# Site Diagram

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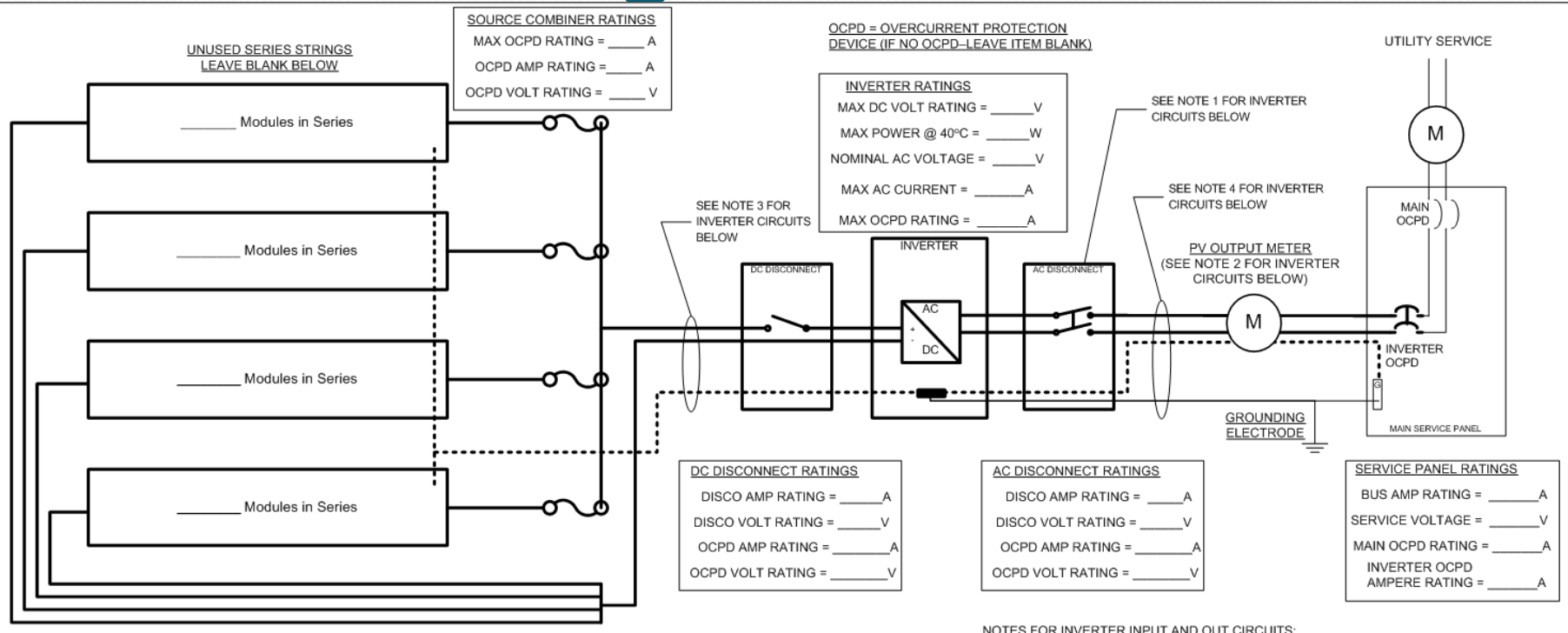
# Electrical Diagram




**PV MODULE RATINGS @ STC**

MODULE MANUFACTURER _____

MODULE MODEL # _____

OPEN-CIRCUIT VOLTAGE = _____V

OPERATING VOLTAGE = _____V

MAX SYSTEM VOLTAGE = _____V

OPERATING CURRENT = _____A

SHORT-CIRCUIT CURRENT = _____A

MAX SERIES FUSE (OCPD) = _____A

MAXIMUM POWER = _____W

Voc TEMP COEFF = ____mV or %/°C
(IF SUPPLIED, CIRCLE TYPE OF COEFF)

**PV ARRAY INFORMATION**

# OF MODULES IN SERIES _____

# OF PARALLEL CIRCUITS _____

LOWEST EXPECTED TEMP _____°C

HIGHEST EXPECTED TEMP _____°C

**690.53 PHOTOVOLTAIC POWER SOURCE SIGN ON DC DISCO**

RATED CURRENT = _____A

RATED VOLTAGE = _____V

MAX SYS VOLTAGE =_____V

MAX CURRENT = _____A

SOURCE CIRCUIT CONDUCTOR TYPE
(OUTSIDE CONDUIT–CIRCLE ONE) USE-2; PV WIRE
SOURCE CIRCUIT CONDUCTOR TYPE
(INSIDE CONDUIT–CIRCLE ONE) THWN-2; XHHW-2; RHW-2; USE-2

SOURCE CIRCUIT CONDUCTOR SIZE
(SEE NOTES FOR ARRAY WIRING BELOW) _____AWG

NOTES FOR ARRAY WIRING:
1.) ASHRAE FUNDEMENTALS OUTDOOR DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PHOENIX, AZ; PALM SPRINGS, CA).
2) FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C,
a) 12 AWG CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 6.4 AMPS OR LESS WHEN PROTECTED BY A 10-AMP FUSE.
b) 10 AWG CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH

NOTES FOR INVERTER INPUT AND OUT CIRCUITS:
1) IF UTILITY REQUIRES VISIBLE-BREAK SWITCH, DOES THE AC DISCONNECT SATISFY THE UTILITY REQUIREMENTS OR IS AN ADDITIONAL SWITCH NECESSARY?
2) IF INCENTIVE PROGRAM REQUIRES PV OUTPUT METER, ADD METER BASE THAT MEETS REQUIREMENTS.
3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON 690.53 SIGN OR OCPD RATING AT DISCONNECT (IF SUPPLIED).
4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING.

Generic Photovoltaic System Electrical Diagram for PV Systems of 10 kW or less

| Drawn By: | SIZE | FSCM NO | DWG NO | REV |
|---|---|---|---|---|
| | A | | E1.1 | 2 |

# SolarTech's Standard Permit Application

**Form PV1**

**Standard Permit Application**
Residential, Roof-Mounted, Grid-Connected PV Systems

This permit application applies to roof-mounted, grid-connected, residential photovoltaic (PV) systems.

Form **PV1-INS** describes the fields in this form in detail.

## 1 Property Owner Information

**Property Owner**

1. Name: _____
2. Installation address: _____
3. Day Phone: (_____) _____ Evening Phone: (_____) _____

## 2 Site Plan

Attach a site plan showing the structure that supports the PV system and the system's location on that structure. The site plan must be on 8.5 x 11 or larger paper.

## 3 Structural Information

### 3.1 Roof Design

1. Weight of array: _____ lbs.
2. Array load concentration: _____ PSF
3. Dead load per support point: _____ lbs.
4. Roofing type (material): _____
5. Roof construction: ☐ **Rafters** ☐ **Trusses** ☐ **Other**: _____
   If trusses or roof joist system are manufactured, skip to **Section 3.2**.
6. Rafter Size: ___ x ___ inches
7. Rafter Spacing: _____ inches
8. Maximum unsupported span: _____ feet, _____ inches
9. Are the rafters over-spanned? (see the IRC span tables in **Form PV1-INS**) ☐ **Yes** ☐ **No**
   If **No**, skip to **Section 3.2**.
   If **Yes**, complete the rest of this section.
10. If the rafters are over-spanned *or* the array is over 5 PSF, it is recommended that you provide one of the following:
    a) A framing plan that shows details for how you will strengthen the rafters.
    b) Confirmation from a professional engineer that the roof structure will support the array.

### 3.2 Wind Design

1. Is the PV system building integrated (BIPV)? ☐ **Yes** ☐ **No**
   If **Yes**, skip to **Section 4**.
   If **No**, complete the rest of this section.
2. Attach one of the following to show that the PV system can support the wind load:
   a) A cut sheet of the roof-mounting system
   b) Calculations of the wind load uplift resistance for the mounts and/or mounting details.
3. Is the PV system tilted over 18 inches above the roof? ☐ **Yes** ☐ **No**
   If **No**, skip to **Section 4**.
   If **Yes**, complete the rest of this section.
4. Wind load: _____ PSF
5. Total wind load on array: _____ lbs.
6. Maximum uplift per support connection: _____ lbs.

# Covers:

1. Property Information
2. Site Plan
3. Structural Analysis
4. System Components
5. Electrical Information



## 4 System Components

| *Component* | *Units* | *Manufacturer and Model Number* |
|---|---|---|
| 1. Photovoltaic Modules: | | |
| 2. Inverter: | | |
| 3. Roof-Mounting System: | | |
| 4. AC Disconnect Switch: | | |
| 5. DC Disconnect Switch: | | |

6. Attach PV module and inverter cut sheets. Attach cut sheets or a detail plan of the mounting system.

## 5 Electrical Information

1. Attach a wiring diagram for the PV system.
2. Complete the following information for EACH inverter ~~w~~With a unique configuration of solar modules.

### 5.1 Array Electrical Specifications

1. Maximum Power Point Current (at STC) Produced by Array: _____ A
2. Short Circuit Current Produced by Array: _____ A
3. Maximum Power Point Voltage (at STC) Produced by Array: _____ V
4. Open Circuit Voltage Produced by Array: _____ V (refer to *NEC* 690.7)
5. STC Watts Produced by Array: _____ W (DC)
6. PTC Watts Produced by Array: _____ W (AC)

### 5.2 Array Wiring and Calculations (DC)

1. Wire type / Size: _____ /_____ AWG
2. Temperature Derated Ampacity of Wire *: _____ A
3. *NEC*-Required Wire Ampacity: _____ A
4. Equipment-Grounding Conductor Size: _____ AWG (refer to *NEC* Table 250.122)

### 5.3 Source Circuits to Inverter Wiring and Overcurrent (DC)

1. Number of Wires / Type / Size: _____ /_____ /_____ AWG
2. Temperature Derated Ampacity of Wire *: _____ A
3. *NEC*-Required Wire Ampacity: _____ A
4. Fuse Size (if applicable) : _____ A
5. Equipment-Grounding Conductor Size: _____ AWG (refer to *NEC* Table 250.122)

### 5.4 Inverter to Grid-Tie Wiring and Overcurrent (AC)

1. Wire type and size: Wire type / size: _____ /_____ AWG
2. Working Voltage: _____ V
3. Temperature Derated Ampacity of Wire *: _____ A
4. *NEC*-Required Wire Ampacity: _____ A
5. Overcurrent Protection (AC breakers) Size: _____ A
6. Equipment-Grounding Conductor Size: _____ AWG (refer to *NEC* Table 250.122)

### 5.5 Maximum System Voltage Calculations

1. Lowest Ambient Temperature for Site: _____ $^{0}$C
2. Low Temperature Voltage Multiplier (per *NEC*) : _____ % (refer to *NEC* Table 690.7)
3. Maximum Voltage (DC) Produced by Array (VOC at STC) : _____ V
4. Maximum System Voltage (DC) at Low Temperature: _____ V
5. AC Grounding Electrode Conductor Size: _____ AWG
6. DC Grounding Electrode Conductor Size: _____ AWG

* Refer to *NEC* Tables 310.16 or 310.17, *NEC* 690.31(A), *NEC* Table 310.15(B)(2)(a), *NEC* 310.10 FPN No. 2

# ICC Tri-Chapter Uniform Code Committee (TUCC)

- **PROPOSED GUIDELINES/**
- Plans submitted for a permit must contain the following items:
- 1) Plan view showing location of the PV installation and layout of existing roof framing members that support the system;
- 2) Details on mounting of PV modules, type and number of roof coverings, and subsequent weatherproofing of the roof;

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# ICC Tri-Chapter Uniform Code Committee (TUCC)

- **PROPOSED GUIDELINES/ (cont)**
- 3) Electrical single-line diagram clearly identifying all devices installed in the PV system and indicating total kVA rating of system;
- 4) Clearly identify the point of interconnection with the utility supplied wiring system and provide details on main breaker, PV breaker and rating of bussing;
- 5) Indicate type and size of all conduit and conductors throughout the PV system;

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- **PROPOSED GUIDELINES/ (cont)**
- 6) Provide manufacturer's cut-sheets and installation instructions for all PV modules, mounting systems, combiner boxes (if used), inverters, and disconnects;
- 7) Provide structural calculations, prepared by a registered California design professional, if the total weight of the photovoltaic system is over five pounds per square foot;
- 8) The installation of the PV system shall conform to the requirements of CEC Article 690 and any other applicable articles or standards.

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# PV Array Layout & Wiring Plan

## PV ARRAY LAYOUT & WIRING PLAN

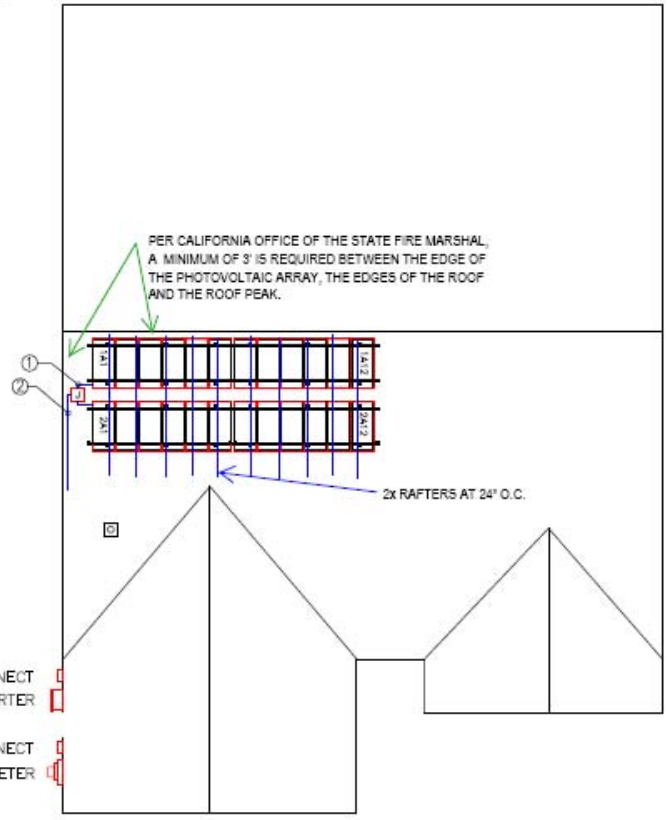
### MOUNTING NOTES

1. PANELS MOUNTED ON ALUMINUM RACKING
2. PV ARRAY MOUNTS TO ROOF STRUCTURE WITH $\frac{5}{16}$" LAGS ENBEDDED $2\frac{1}{2}$" INTO RAFTERS OR SEE NOTE 5 BELOW
3. PV PANELS ARE ANCHORED @ 48" O.C. TRUSSES/ RAFTERS ARE 24"O.C. OR SEE NOTE 5 BELOW
4. WEIGHT OF PV MODULES AND ASSMEBLY LESS THAN 5 LBS PER SQAURE FOOT
5. ALL INSTALLATIONS MUST COMPLY WITH MANUFACTURER'S INSTALLATION INSTRUCTIONS.

### ARRAY CONDUIT & WIRING ARRANGEMENT

1. FREE-AIR / ½" CONDUIT SLEEVE**
   (2) #12 AWG; R, W
2. TO DC DISONNECT
   1/2" CONDUIT
   (4) #12 AWG; (2)R, (2)W
   (1) #8 GND

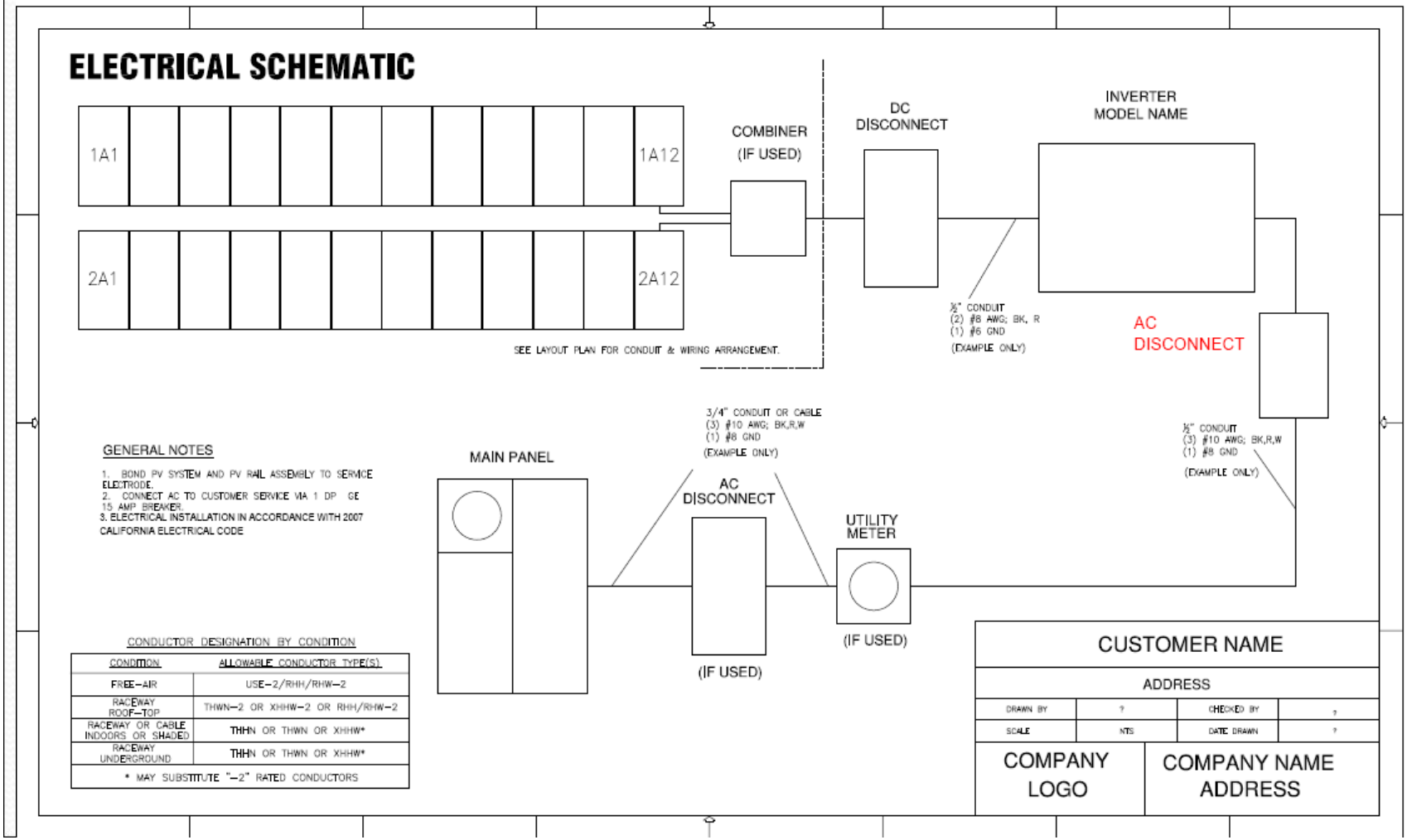
** SLEEVE PROMOES PROTECTION FROM PHYSICAL DAMAGE PER NEC 300.13 & 300.18




SITE MAP

| CUSTOMER NAME | | | |
|---|---|---|---|
| ADDRESS | | | |
| DRAWN BY | ? | CHECKED BY | ? |
| SCALE | NTS | DATE DRAWN | ? |
| COMPANY LOGO | | COMPANY NAME ADDRESS | |

# Electrical Diagram



# Next Steps

- Pursue safety, quality, and streamlined process relentlessly.
- Continue to work on consensus documents to simplify the permitting and inspection processes.
- SolarTech/CalSEIA Summit in April, 2009.

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